Harnessing information from new satellite observations of PAN in the troposphere

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Award #:
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PAN retrievals have a role to play in addressing knowledge gaps in how atmospheric composition is changing?

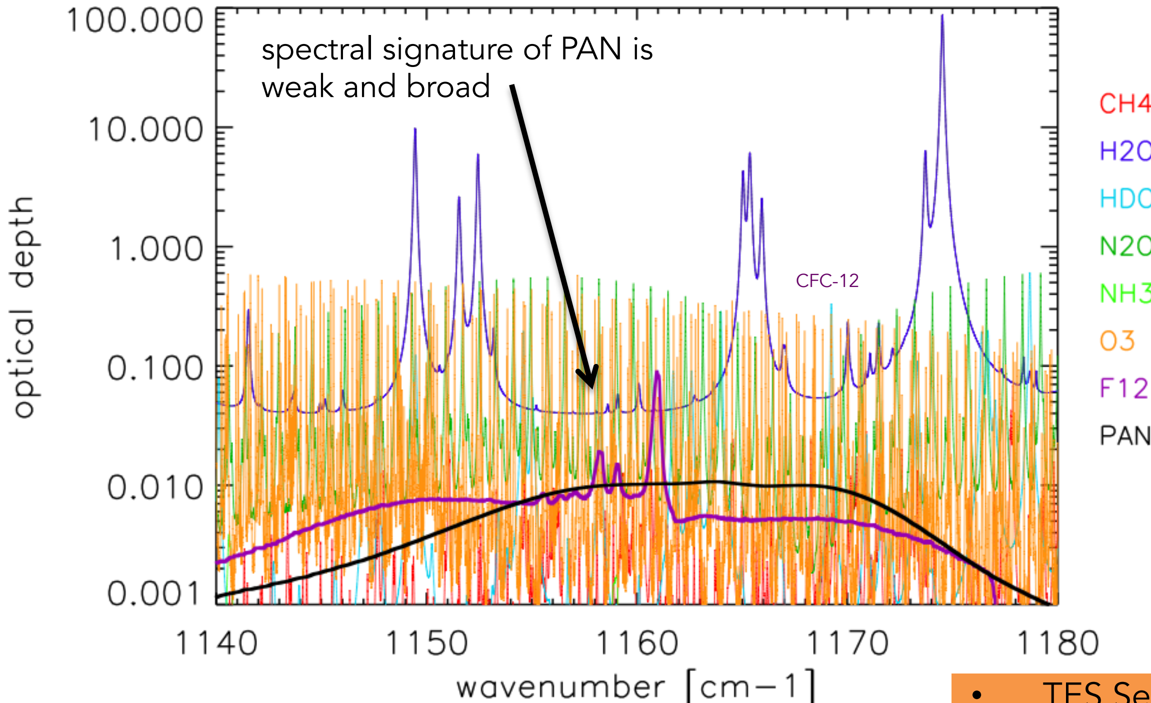
Emissions (and distributions) of NO_x are changing rapidly.
PAN has/will re-distribute the impacts on oxidants.

PAN indicates past photochemistry and its transport.
With adequate sensitivity, PAN is a way to "follow along."

TES PAN provided many new insights
And identified model inadequacies.

TES paved the way. CrIS is the future.
Used together, I bet we can see changes.

2014 – 2018 challenge: Harness TES PAN measurements to verify and understand key global features.

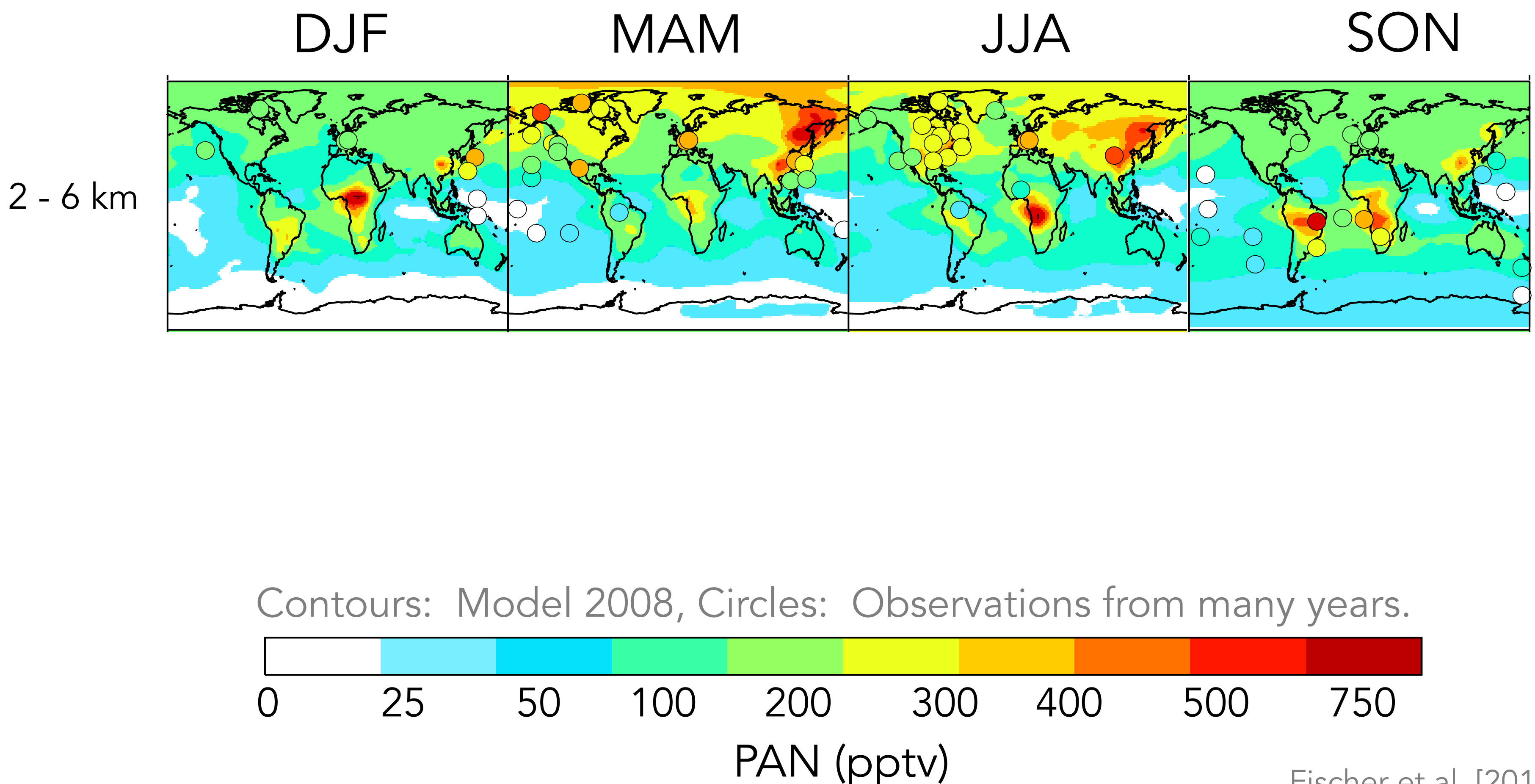


Major advances in our understanding of the global distribution of this keystone species despite a high detection limit and no vertical information!

- TES Sensitivity:
  - Mid-upper troposphere
  - DOFS < 1.0
- Limit of detectability: ~0.2 ppbv
  - TES only sees elevated PAN
- Estimated errors: 30-50 %
- Impact of clouds:
  - Large enough PAN signal:
    - TES will see it with/without cloud
  - Borderline PAN signal:
    - May be obscured by cloud

Payne et al. [2014]

PAN "lives" at different altitudes over different locations. We can learn about it from TES, even without vertical information.



Fischer et al. [2014]

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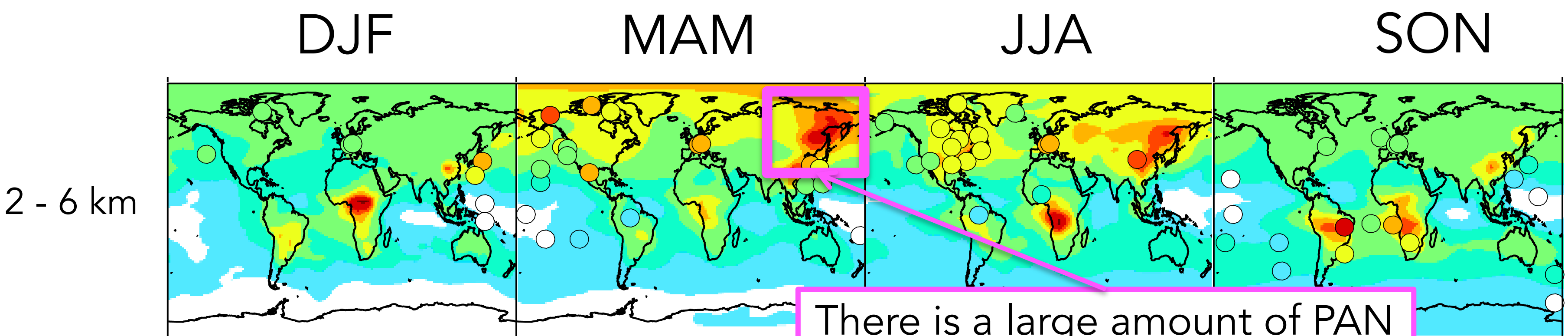
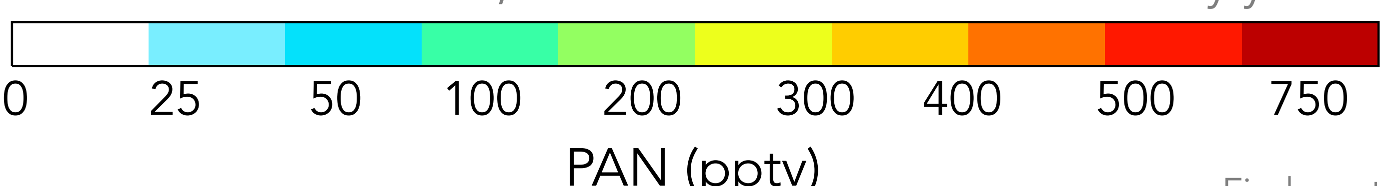


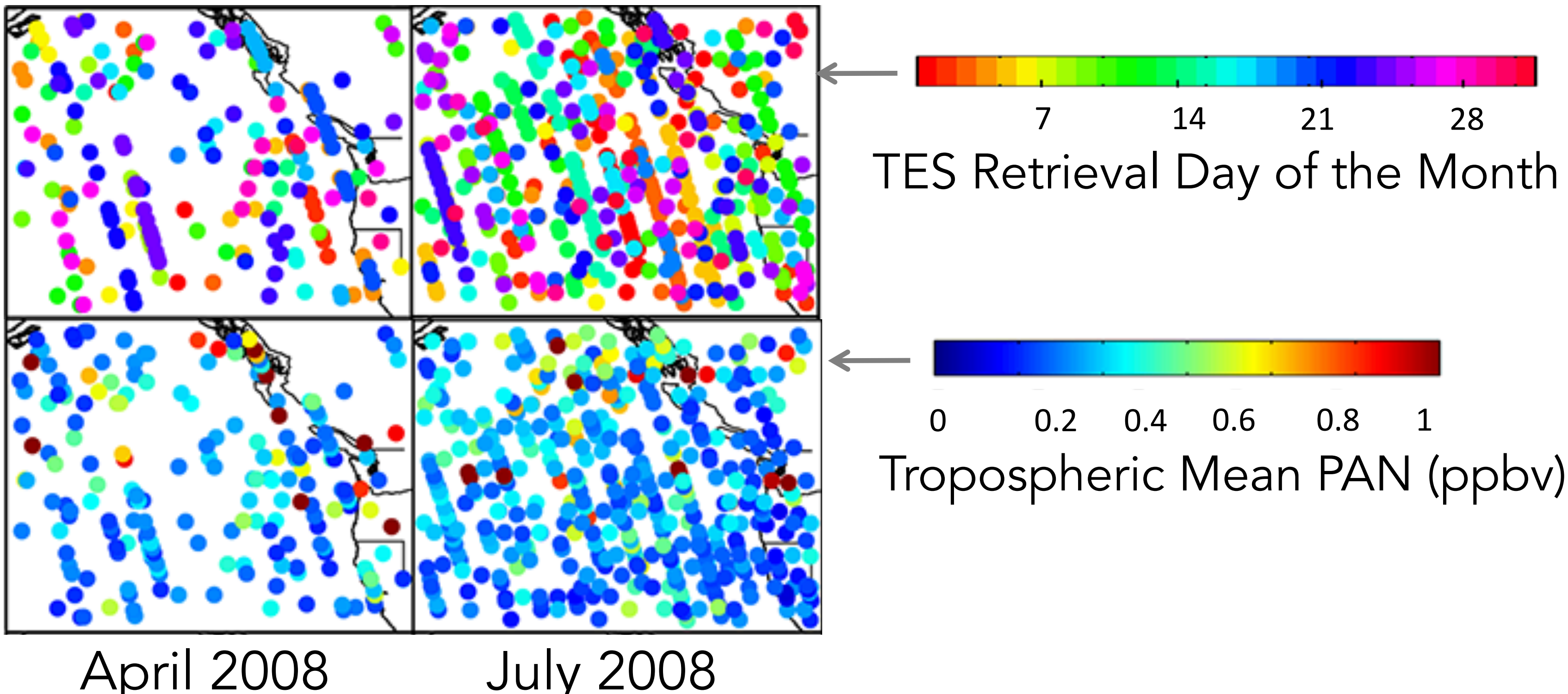
There is a large amount of PAN leaving East Asia. Fires contribute, there is high IAV, and anthropogenic emissions are changing rapidly.

Contours: Model 2008, Circles: Observations from many years.



Fischer et al. [2014]

PAN plumes (i.e. > LOD) are present every day in July.



Zhu et al. [2017]

Trends can be more quickly detected in summer.
Detection likely faster with TES (and CrIS?) than with surface obs.

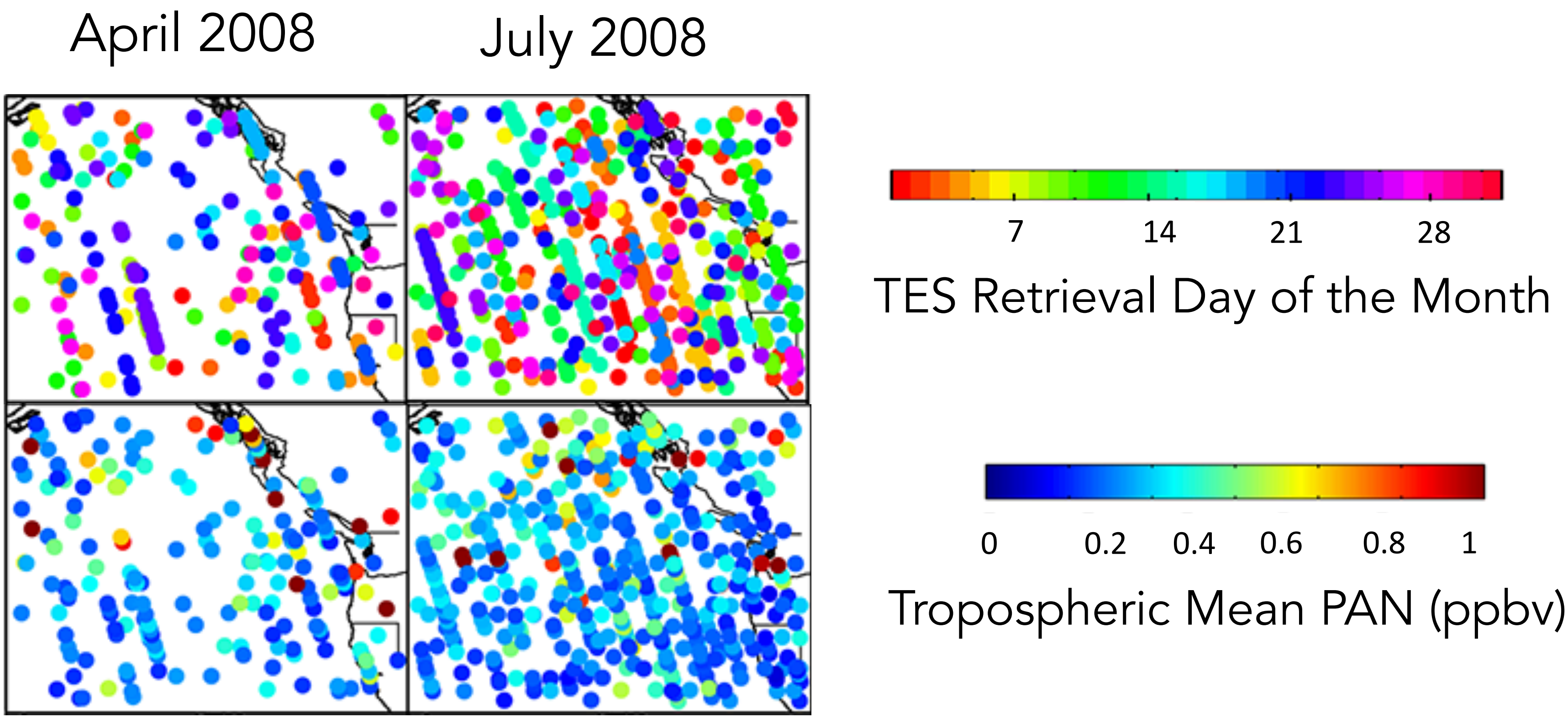


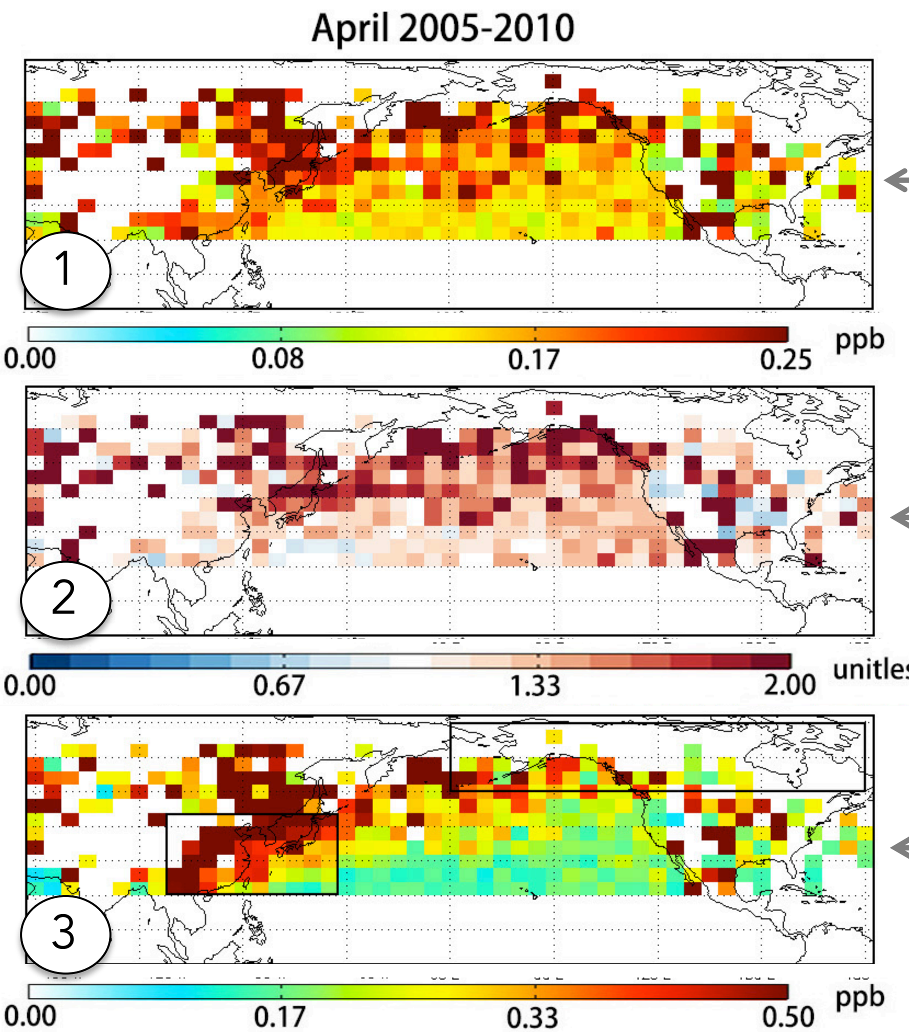
Table 1. Number of Years to Detect a Range of Real Trends of PAN Over the Eastern Pacific Ocean Using TES PAN Retrievals in Springtime and Summertime, Respectively[a]

Increasing rate in PAN (% yr^{-1})	2	3	4	5	6
Years (based on April retrievals)	14	11	10	8	8
Years (based on July retrievals)	10	8	7	6	6
Years (based on springtime observations at MBO site) [*Fischer et al.*, 2011]	20	15	13	11	10

[a] A real trend is indicated at the 95% confidence level. The third row is years calculated based on springtime observations at one surface site Mount Bachelor (MBO) from *Fischer et al.* [2011].

Zhu et al. [2017]

TES PAN observations can be used to adjust GEOS-Chem. Adjustments in East Asia were upward.



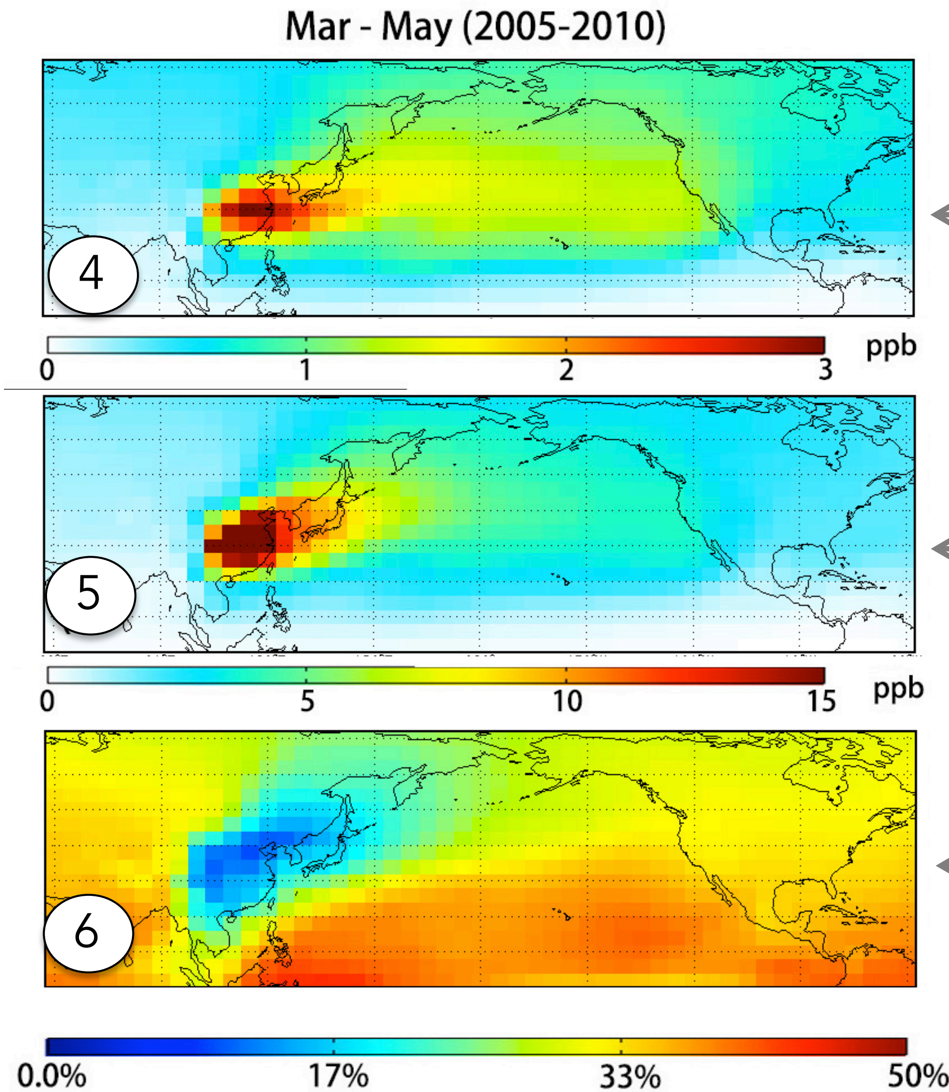
Multi-year monthly mean TES PAN measurements

Scaling factors: ratio of TES PAN measurements over smoothed model

GEOS-Chem simulation, adjusted with the scaling factors.

Jiang et al. [2016]

Improved model can be used to estimate that a large fraction of free tropospheric (FT) O_3 is a result of PAN chemistry.



FT O_3 produced from East Asian PAN.

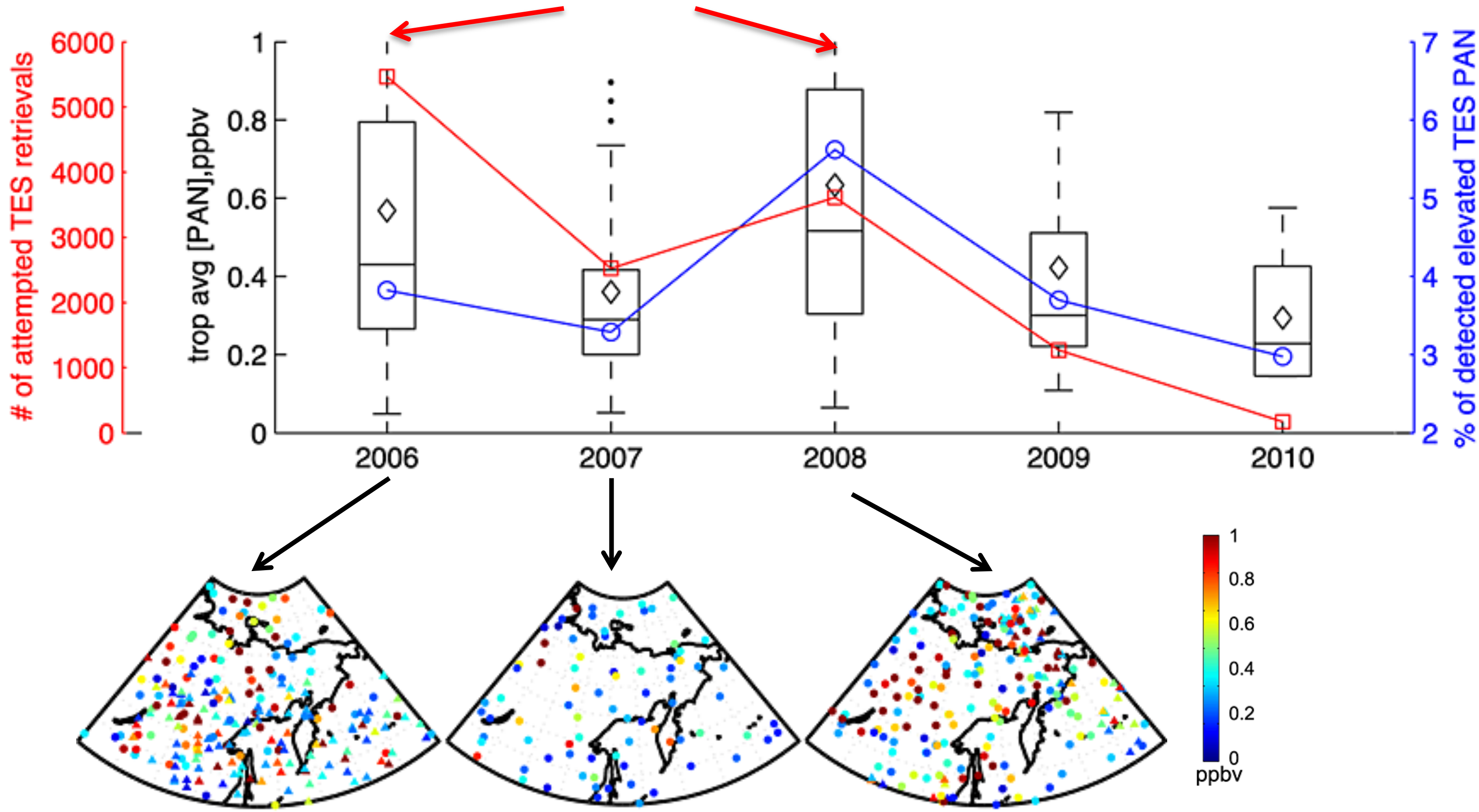
FT O_3 produced from East Asian NO_x emissions.

Relative contribution of PAN FT O_3

Jiang et al. [2016]

Periods of elevated fire activity contribute to the inter-annual variability; temperature and vertical mixing also matter.

TES Special Observations:
More Data
But also a higher % of success!



Special observations are marked as triangles.

With Special Obs. removed, distributions remain similar. Means are the same.

Zhu et al. [2015]

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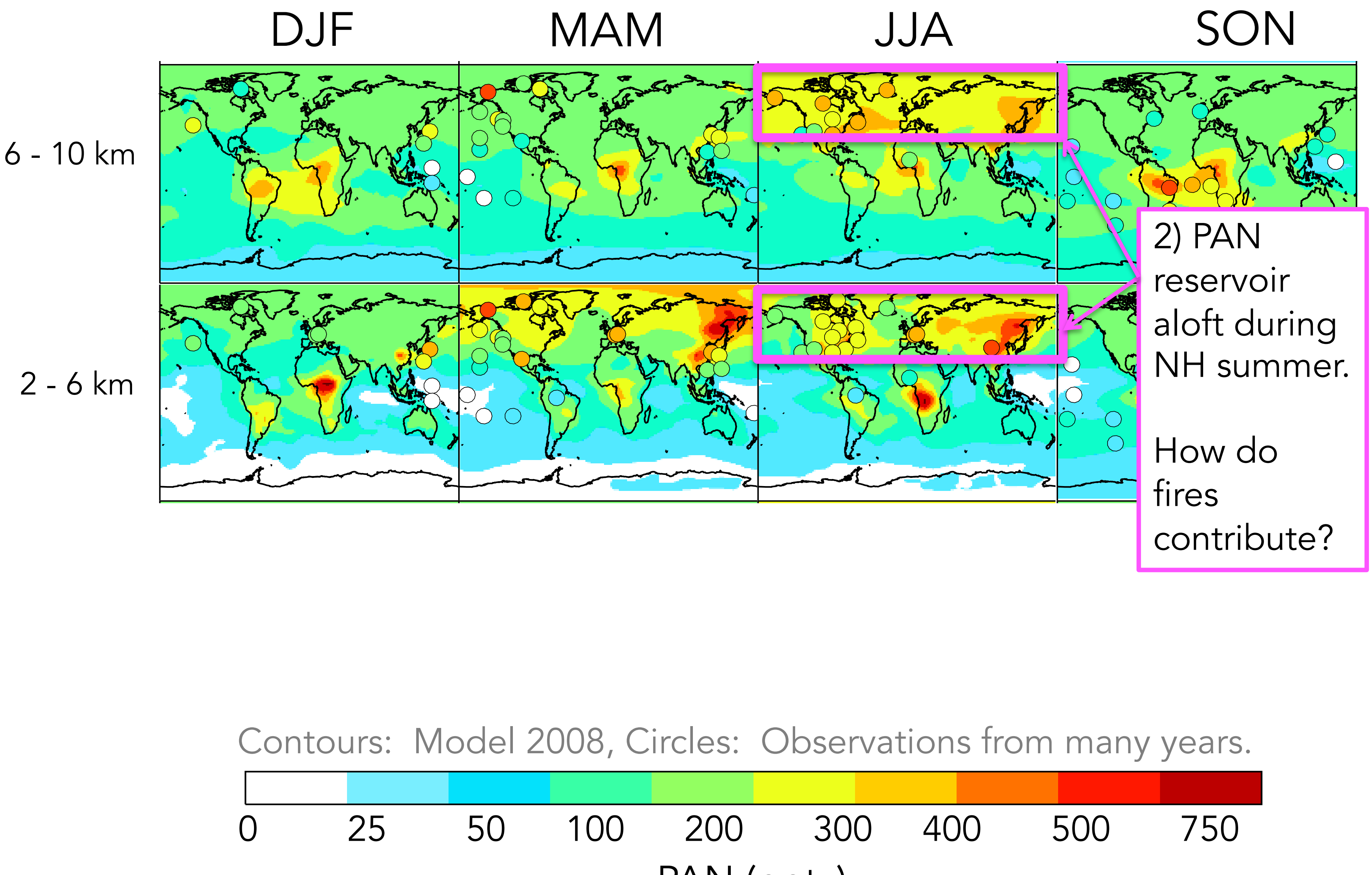
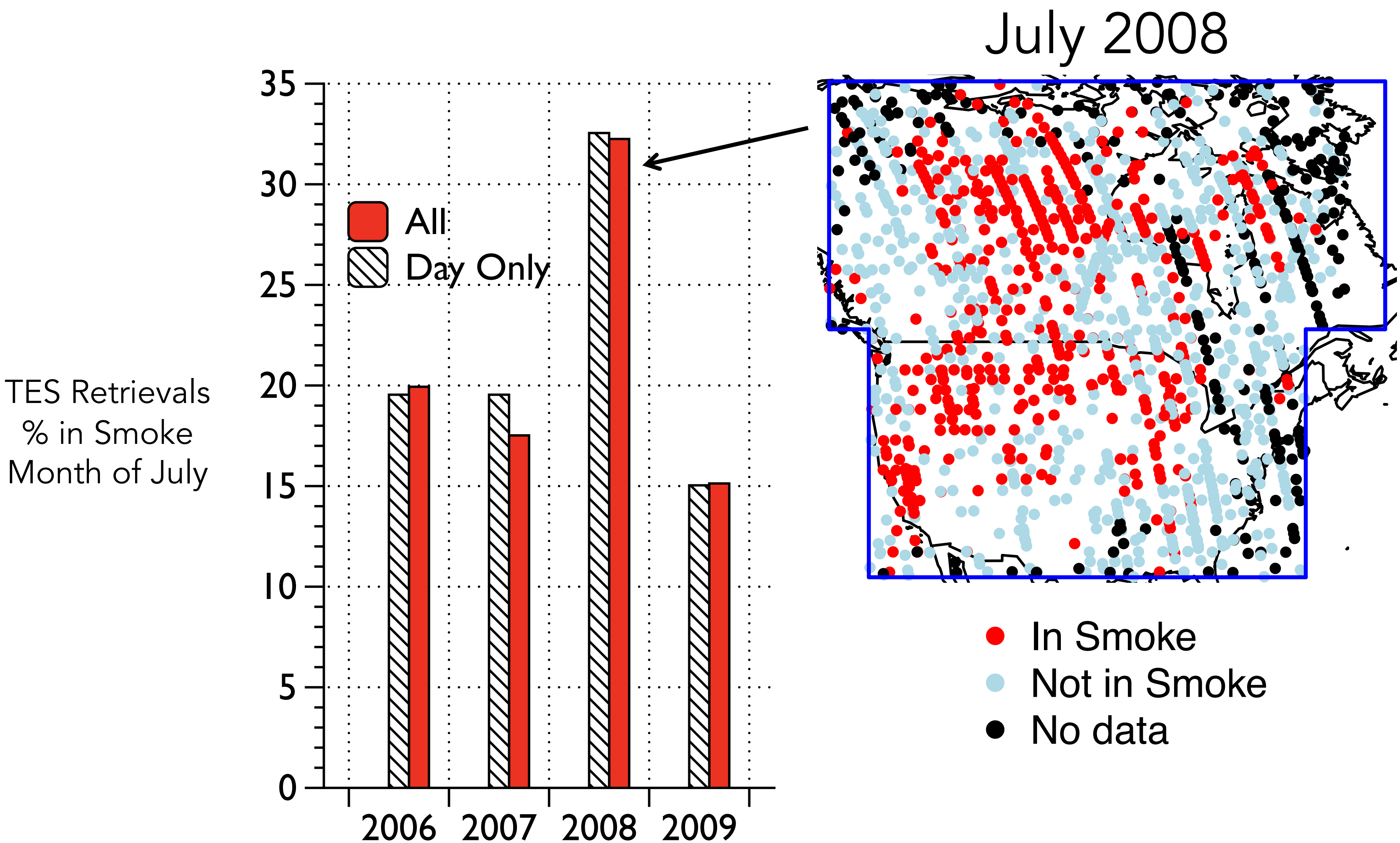


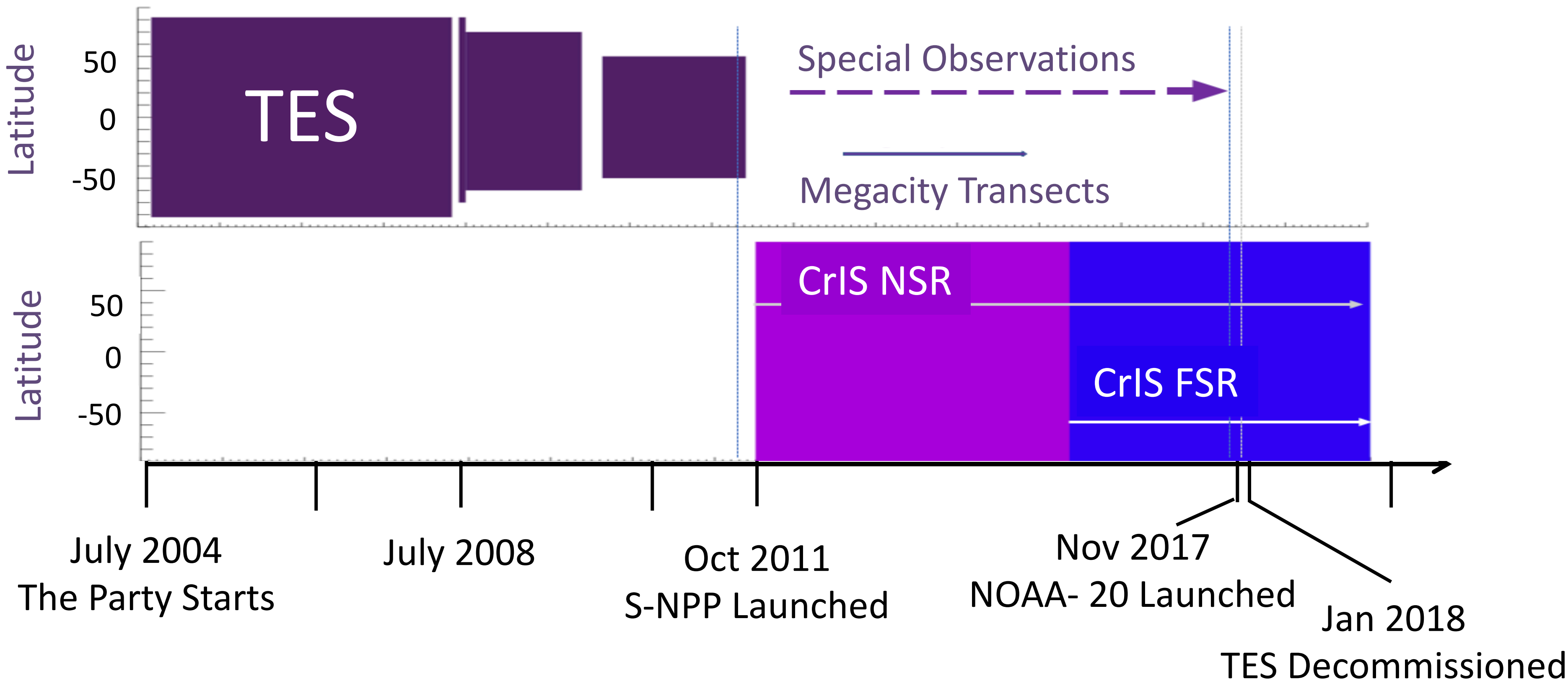
Fischer et al. [2014]

A large fraction of PAN plumes over N. America in summer are caused by wildfires. Plumes are detected days downwind.

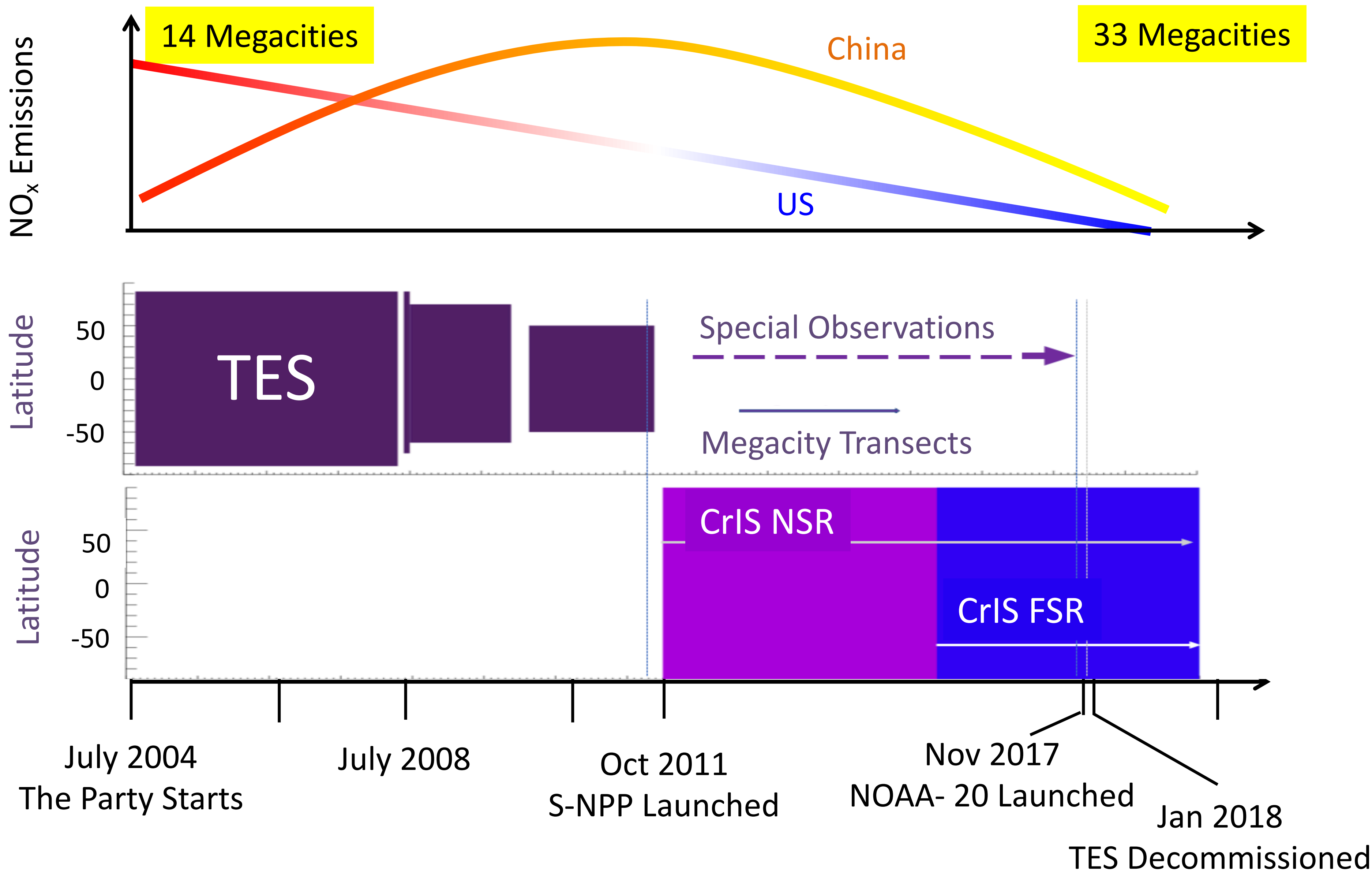


Fischer et al. [2018]

Looking back and moving forward requires TES. How do we leverage an emerging global long-term record of PAN?



This record crossed a very dynamic period of NO_x emissions in the Northern Hemisphere, and a rise in megacities.



Questions?

Fischer, E. V., Zhu, L., Payne, V. H., Worden, J. R., Jiang, Z., Kulawik, S. S., Brey, S., Hecobian, A., Gombos, D., Cady-Pereira, K., and Flocke, F. (2018), Using TES retrievals to investigate PAN in North American biomass burning plumes, *Atmos. Chem. Phys.,* 18, 5639-5653, https://doi.org/10.5194/acp-18-5639-2018, 2018.

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Zhu, L., E. V. Fischer, V. Payne, J. Worden and Z. Jiang (2015), TES Observations of the Interannual Variability of PAN over Northern Eurasia and the Relationship to Springtime Fires, *Geophys. Res. Lett*., DOI:10.1002/2015GL065328.

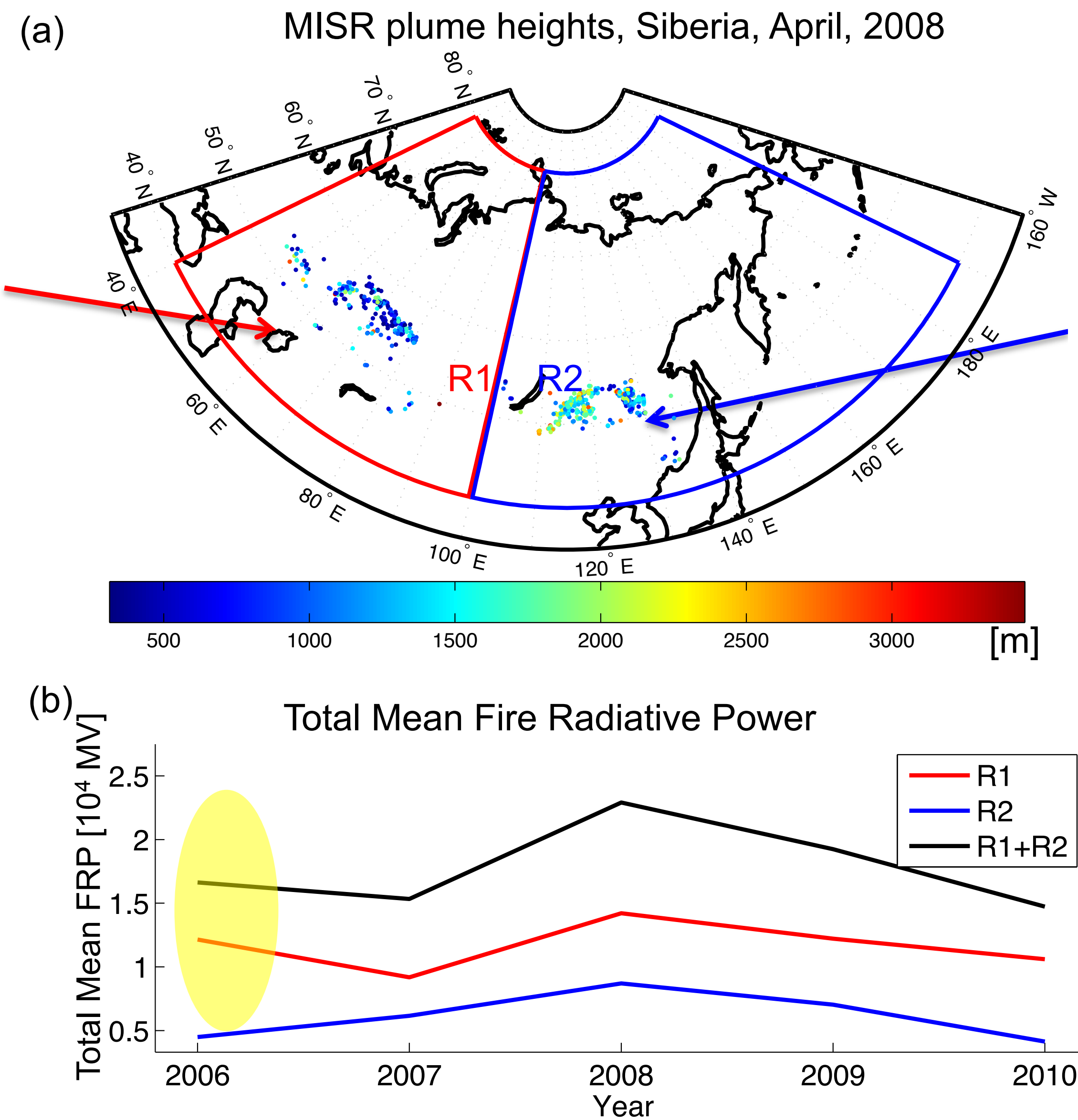
Zhu, L., V. Payne, T. Walker, J. Worden, Z. Jiang, S. S. Kulawik, and E. V. Fischer (2017), PAN in the Eastern Pacific Free Troposphere: A Satellite View of the Sources, Seasonality, Interannual Variability and Timeline for Trend Detection, *J. Geophys. Res. Atmos*., 122, doi:10.1002/2016JD025868.

Zhu, L., M.Val Martin, A. Hecobian, L. V. Gatti, R. Kahn, and E. V. Fischer (2018), Development and implementation of a new biomass burning emissions injection height scheme (BBEIH v1.0) for the GEOS-Chem model (v9-01-01), *Geosci. Model Dev.,* 11, 4103-4116, https://doi.org/10.5194/gmd-11-4103-2018, 2018.

Extra Stuff

Periods of elevated fire activity contribute to the inter-annual variability; temperature and vertical mixing also matter.

Elevated fire activity in 2006 and 2008. Lower plume injection heights.



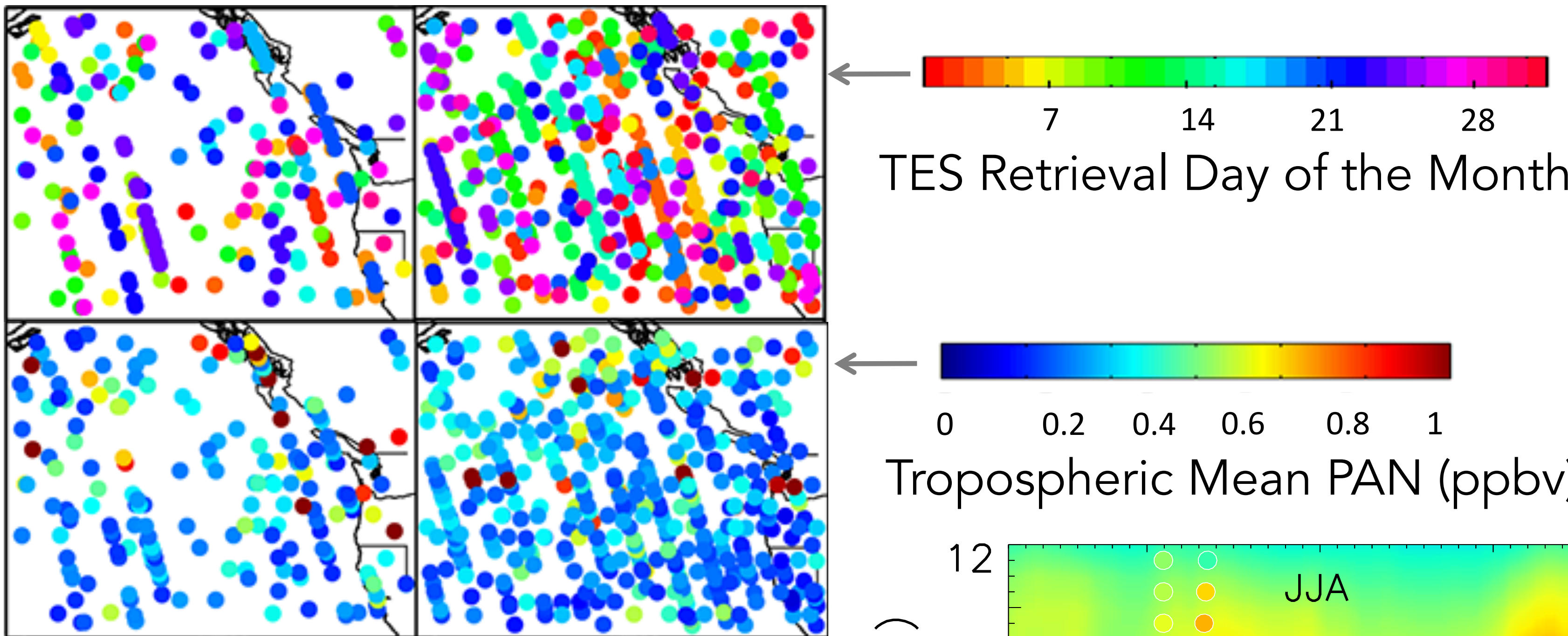
Elevated fire activity in 2008. Higher plume injection heights.

April 2006 was colder (e.g. 9°C colder in 2006 than 2007) and there was more vertical mixing.

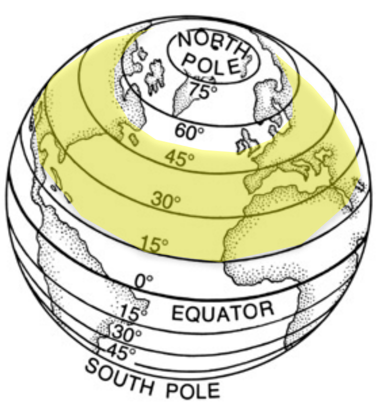
Zhu et al. [2015]

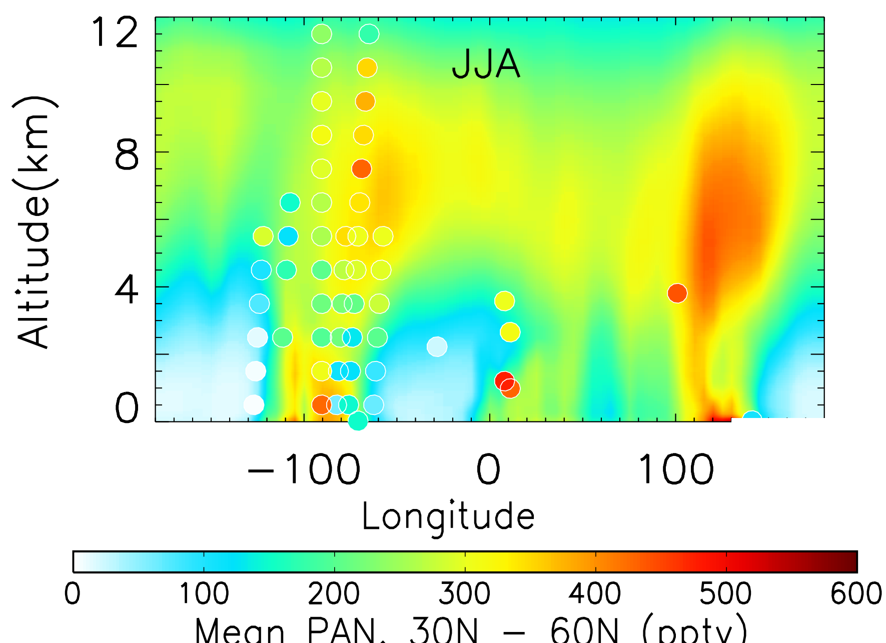
PAN plumes (i.e. > LOD) are present every day in July.

There is a reservoir aloft.



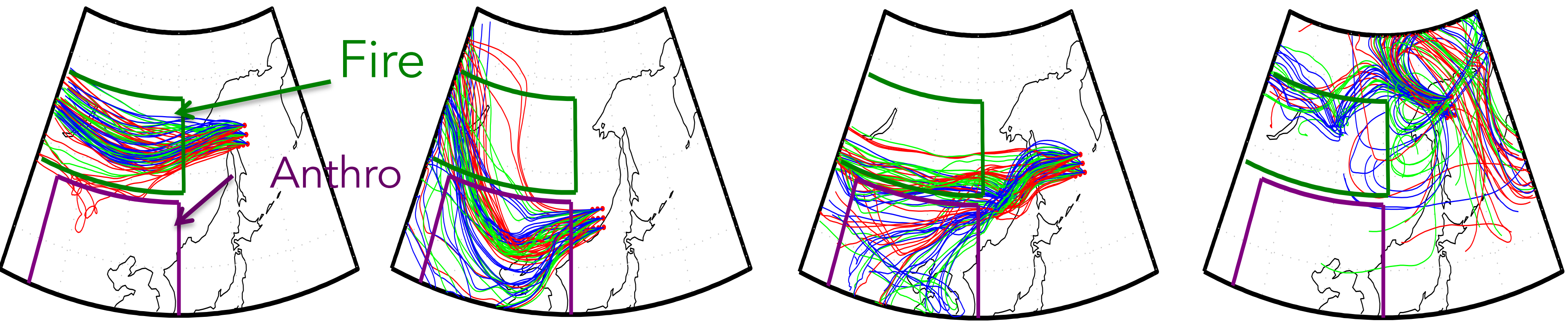
April 2008 July 2008





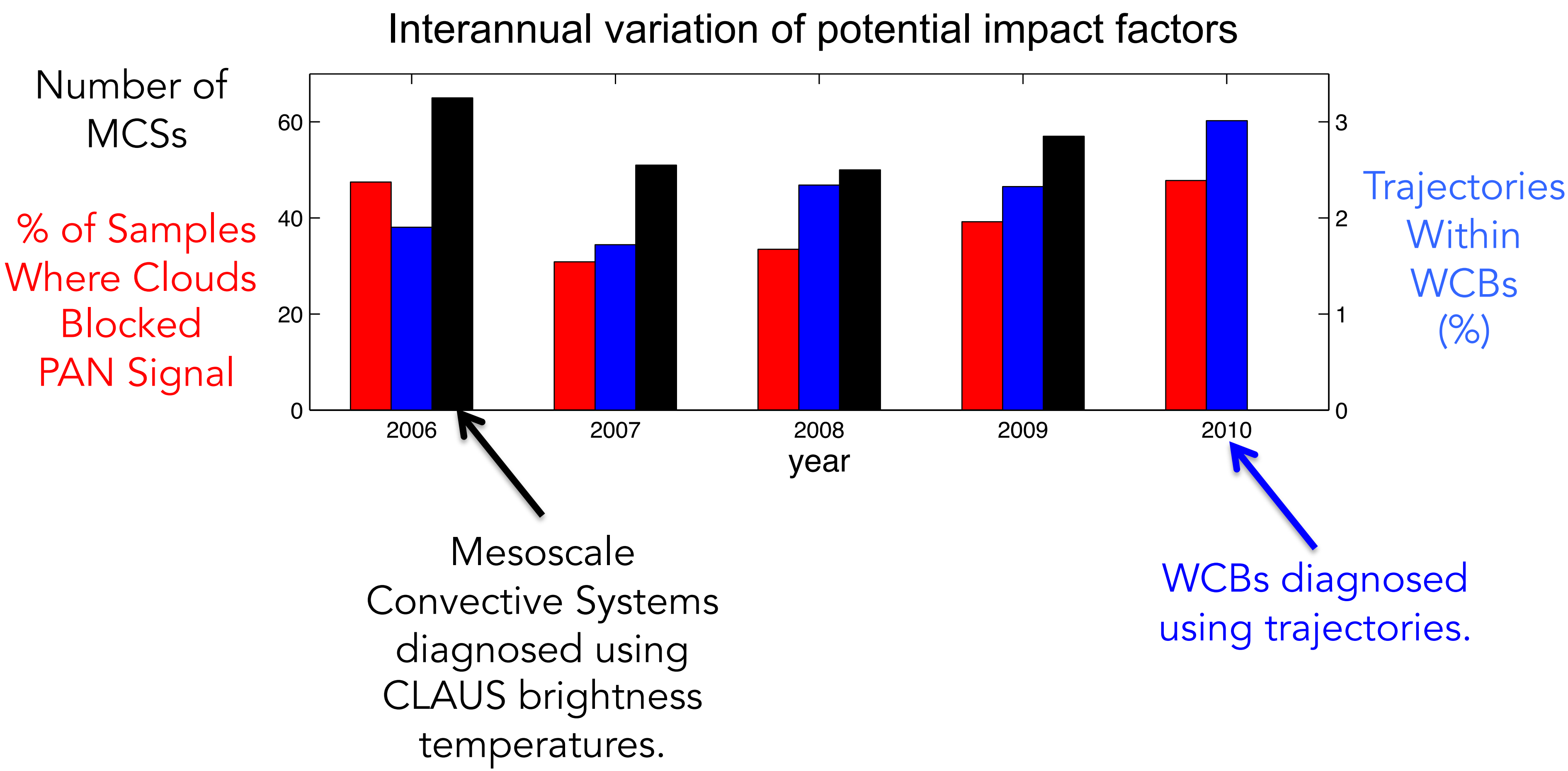
Zhu et al. [2017]

HYSPLIT trajectories: a large fraction of PAN during 2006 and 2008 was from areas with biomass burning.



	Fire	Anthropogenic	Fire and Anthropogenic	Unclassified
April 2008	57%	13%	2%	29%
April 2006	36%	11%	5%	49%

April 2006 was colder (e.g. 9°C colder in 2006 than 2007) and there was more vertical mixing.



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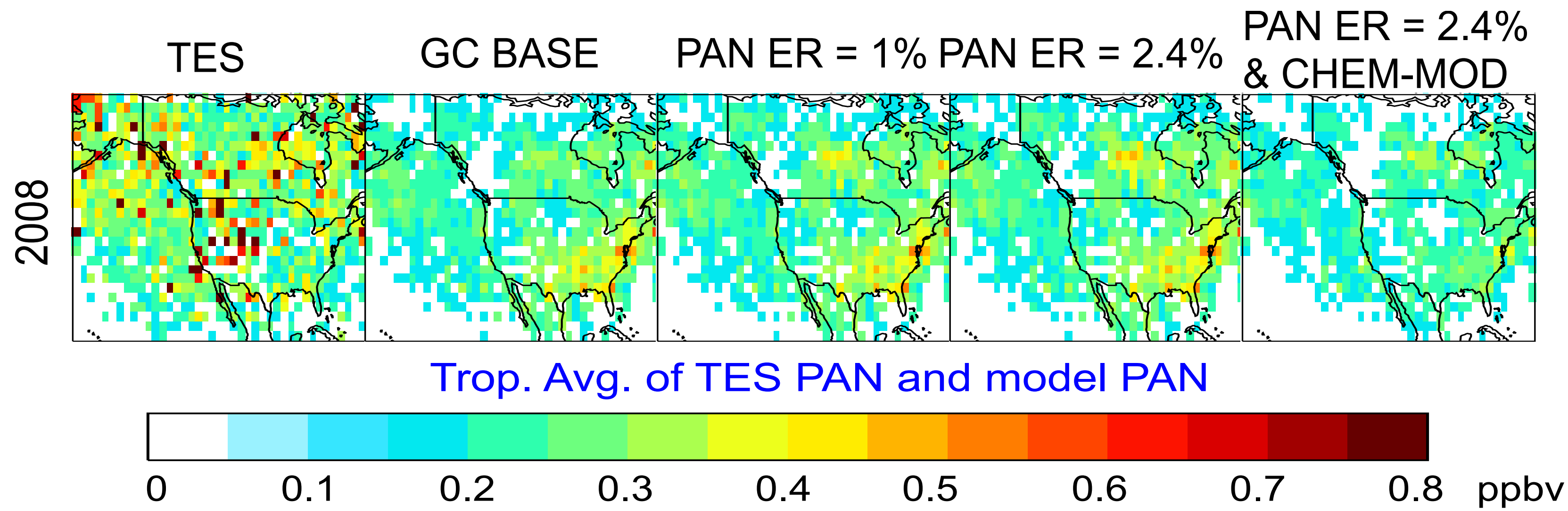
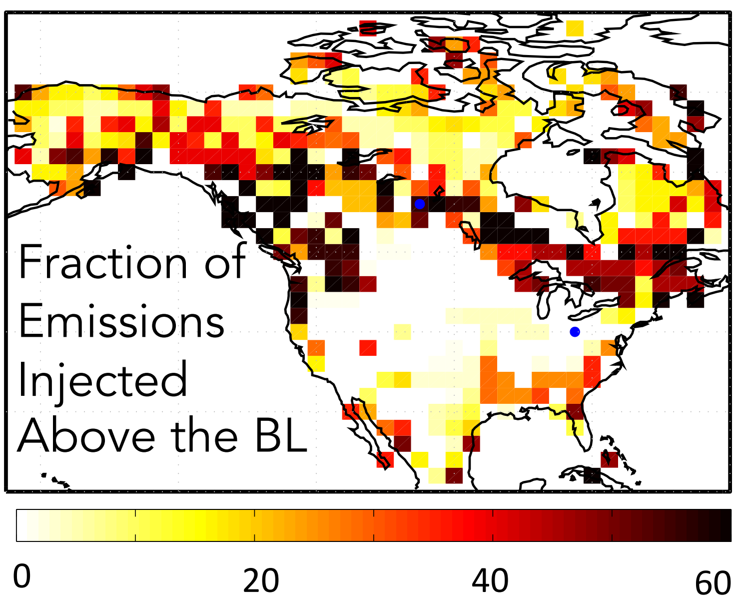
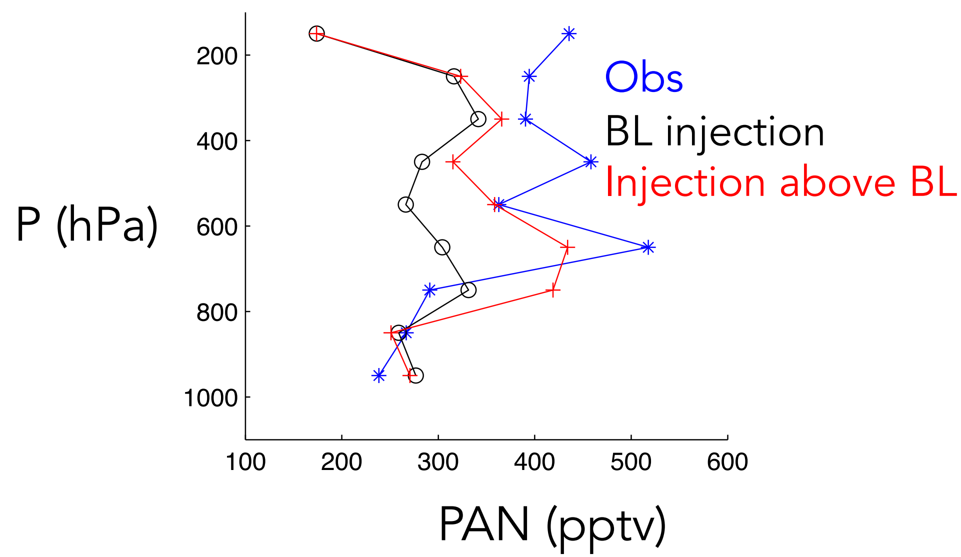
PAN enhancements (and thus the O_3 production from the largest wildfires) without more realistic injection heights.

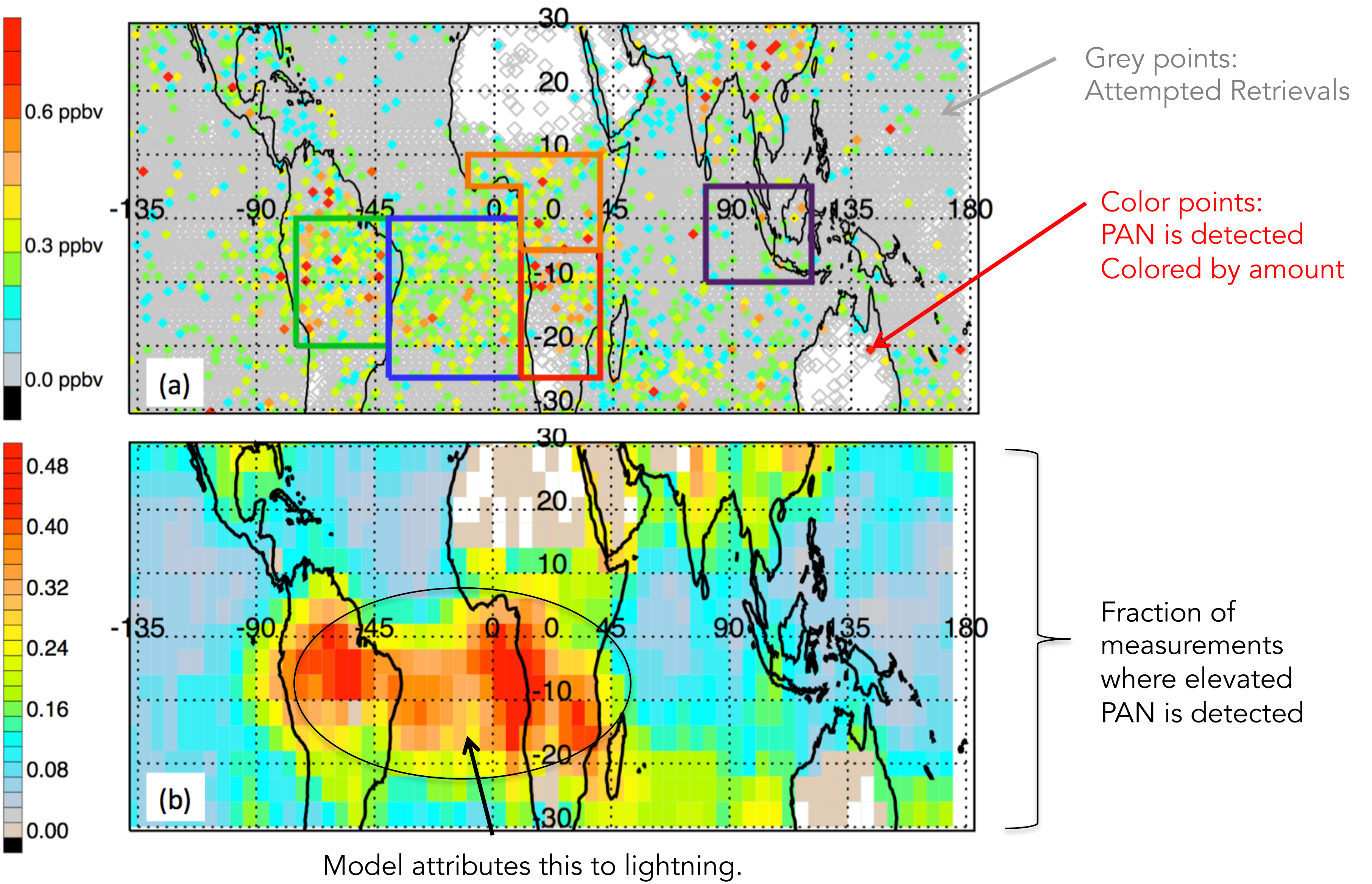






Zhu et al. [2018]

There is an austral spring maximum in PAN over the tropical Atlantic. It was consistent in 2005 and 2006 despite IAV in BB.



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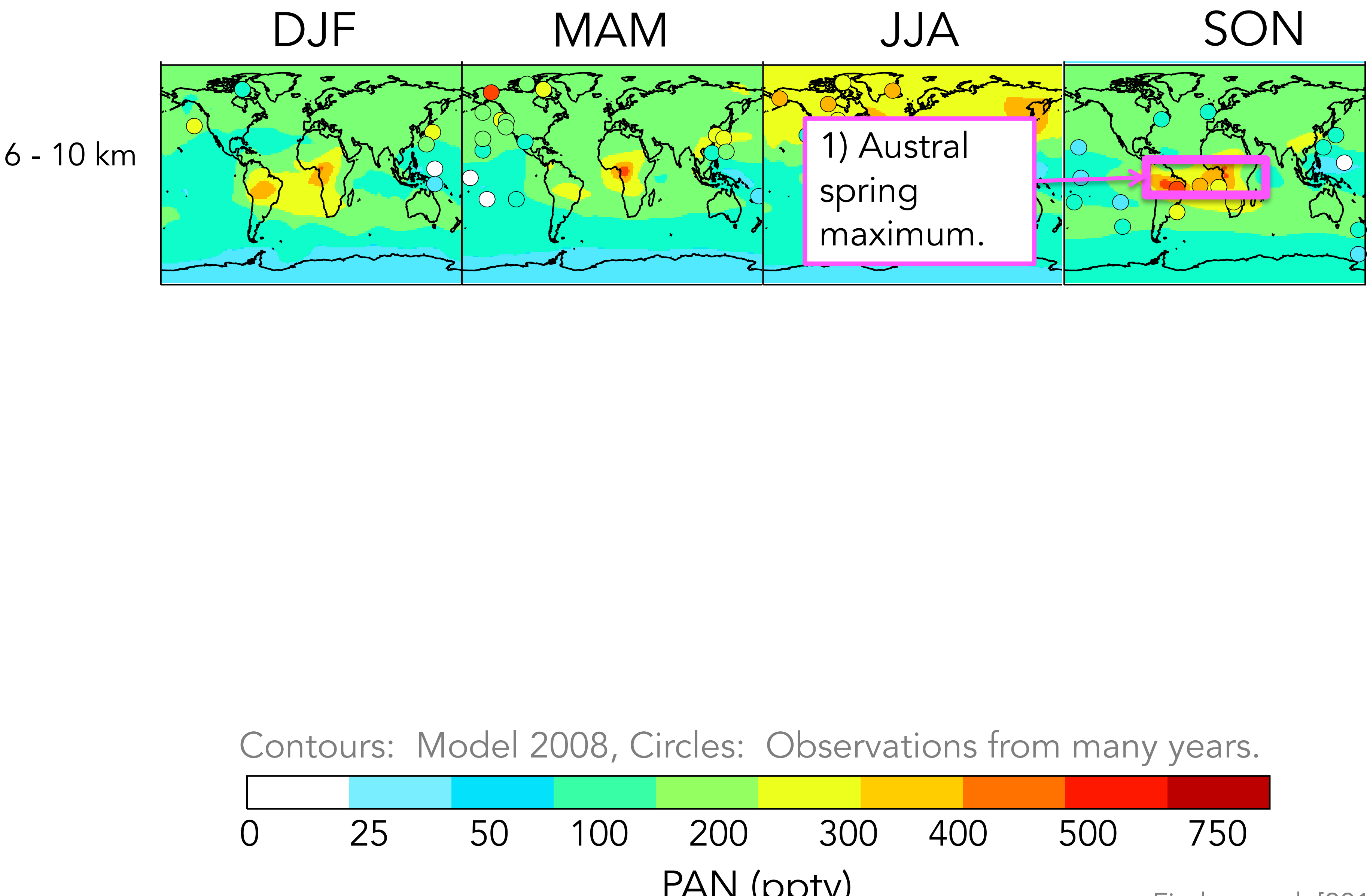

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